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**THE IMPACT OF LATENT RISK PREFERENCES ON VALUING
THE PRESERVATION OF THREATENED LYNX POPULATIONS
IN POLAND**

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Abstract

A recent innovation in stated preference environmental valuation surveys is to acknowledge uncertainty associated with scientific predictions about ecological outcomes, complexity of management actions and potential difficulties in implementing environmental programs. Still little is known about how individuals assimilate and respond to outcome uncertainty, particularly in terms of how it affects their stated valuations. In this paper, we focus on the impact of individual risk preferences on willingness to pay for conservation of threatened species. Risk preferences are elicited through a standard incentivised multiple price list (MPL) and preferences for the conservation of the two main lynx populations in Poland through a discrete choice experiment (CE). To account for the uncertainty associated with imprecise scientific knowledge about environmental outcome, attributes in the CE are presented as conservation status in terms of descriptive, non-numerical categories. The results from the MPL and the CE are jointly analysed in a latent variable model by assuming that the responses to both are driven by the same preferences. We find that the latent risk preferences are linked to choices of the status quo option, which is the riskiest option in terms of the survival of the endangered lynx populations.

Keywords: choice experiment, hybrid latent class model, lottery experiment, lynx preservation, risk preferences

1. Introduction

It is a common practice in stated preference valuation surveys to assume that the environmental outcomes are certain; however, this contrasts with the situation in the real world. Owing to limited knowledge on natural processes and the fact that environmental improvements often involve very long time horizons, the outcomes of conservation policies can entail substantial uncertainty. Uncertainty can be associated with imprecise scientific knowledge about environmental outcomes or with complexity of management actions and the difficulties of achieving policy effectiveness connected with the possible changes to the political, social and economic environment (Glenk and Colombo 2013). Rolfe and Windle (2015) point out that the omission of uncertainty about environmental outcomes may contribute to the hypothetical bias in stated preferences surveys, because it influences the credibility of the valuation scenario. Given that the outcomes of environmental protection plans can never be known with certainty, researchers need to make judgments about how to comprise this uncertainty into survey designs (Lew et al., 2010).

Recently, several choice experiments (CE) studies published in the field of environmental valuation have aimed at incorporating uncertainty associated with scientific predictions about ecological outcomes or connected with the effectiveness of different delivery mechanisms into their designs. The following approaches can be distinguished: firstly, uncertainty or risk¹ can be provided as a part of the valuation scenarios. This approach is applied, e.g. by Wielgus et al. (2009) in a CE survey concerning fishing preferences, where respondents were assigned to three split samples and presented with questionnaires in which the probability of occurrence of the valuation scenarios varied. Secondly, risk can be assigned to a single attribute presented in the CE or to alternatives (management options). Rigby et al. (2010), e.g., specified one of their attributes as the probability of rainfall levels, while Glenk

¹ For risky outcome we assume known outcomes with a known probability in numerical terms, whereas uncertainty entails randomness with unknowable probabilities.

and Colombo (2013) incorporated as an attribute the probability that a soil carbon program might actually fail to deliver climate change mitigation benefits. Rolfe and Windle (2015) in their CE study regarding the Great Barrier Reef protection include a separate attribute for the certainty of outcomes presented in numerical terms. Deliberately, however, alternative outcomes are not described precisely to respondents to assess uncertainty rather than risk.

Another approach of how to incorporate uncertainty is presented by Wielgus et al. (2009) in their survey concerned with divers. Instead of providing the probability of event they incorporate uncertainty by specifying attribute levels as intervals reflecting the varying number of coral fish observed during one dive. In studies investigating the public's preferences for enhancements to the protection of marine species Lew et al. (2010) and Lew and Wallamo (2011) use as attributes the conservation status of marine species accounting for potential outcome uncertainty. This conservation status is based on categories defined in the US Endangered Species Act (ESA). All these approaches mean a step forward in contrast to studies where environmental outcomes were – explicitly or implicitly – presented as certain. However, how individuals understand and respond to this uncertainty, particularly how it affects their values, remains an open question.

In this paper, we focus on the impact of risk preferences on stated preferences. Risk preferences have been shown to influence behaviour in a number of other domains where uncertainty is a key feature of future outcomes, such as health protection, financial investments, job changes or driving behaviour (e.g., Anderson and Mellor 2008; Kimball et al. 2008; Hakes and Viscusi 2007). Some studies have tested whether risk preferences measured in an experimental way are linked with real risky behaviour. Anderson and Mellor (2008), e.g., show that individuals who are more risk-averse are less likely to smoke and more likely to wear seatbelts. Elston et al. (2005) report that full-time entrepreneurs are less risk-averse than non-entrepreneurs and that part-time entrepreneurs were more risk-averse than

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3 non-entrepreneurs. Lusk and Coble (2005) found that risk preferences are significant
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5 determinants of the acceptance of genetically modified food. Meanwhile, Olbrich et al. (2011)
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7 report that adult farmers in Namibia self-selected themselves onto farms according to their
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9 risk preferences (i.e. those with lower risk aversion were found on farms with higher
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11 environmental risks).
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14 The main objective of our analysis is to examine the impact, if any, of individual risk
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16 preferences on stated willingness to pay (WTP) for lynx conservation in Poland. The first part
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18 of the study is a choice experiment designed to value the preservation of the two main lynx
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20 populations in Poland, the Lowland population that occupies the north-eastern part of the
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22 country and the Carpathian located in the south. Both populations are exposed to a high risk
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24 of becoming extinct. Mostly, this is the result of the rapid growth of transport infrastructure
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26 and insufficient protection programmes.
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30 The outcomes of the conservation programmes presented in the CE were specified as
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32 uncertain to reflect scientific reality due to imprecise scientific knowledge about
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34 environmental processes. Following Lew et al. (2010) and Lew and Wallamo (2011) as
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36 attributes we use conservation status of species, in our case based on the International Union
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38 for Conservation of Nature (IUCN) Red List of Threatened species. Due to limited knowledge
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40 of environmental processes some biologists refuse to define the exact size of the population or
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42 to assign numerical probabilities about environmental outcomes. Both the IUCN and the ESA
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44 present the conservation status of wild species and their links to livelihoods in terms of
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46 descriptive, non-numerical categories. If the outcomes of programs are presented just as the
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48 number of animals and associated probabilities of survival, it can be misleading, since the
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50 chances of survival do not depend solely on the population size. Other factors such as size of
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52 habitat or migration possibilities may also influence the species status.
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The second part of the study is designed to elicit respondents' risk preferences. In this part, we utilise the standard multiple price listing (MPL) approach originally proposed by Binswanger (1980) and later modified and popularized by Holt and Laury (2002). In the MLP experiment conducted by Holt and Laury individuals made ten choices between two lotteries. For each lottery, payoffs are fixed, but the probabilities vary. Rewards are structured such that one lottery is less risky than the other. To estimate risk preferences, the expected gains in two subsequent choices are compared, assuming the relative risk aversion functional form is constant. Robustness of the MPL design was investigated in a few studies e.g. Anderson et al. (2007) found it to be robust to framing effects whereas Harrison et al. (2005) and Holt and Laury (2005) found that scaling up real payments had no impact on hypothetically elicited risk aversion coefficients.

Given the current unresolved issues with respect to the direct elicitation and interpretation of environmental risk preferences (see Riddle, 2012), we chose to elicit financial risk preferences as they have the best theoretical foundation, at least to date. From the experimental literature there is evidence that risk preferences elicited in the financial domain may be linked with environmental decisions. Grijalva et. al (2011) show in their study conducted among students that risk preferences elicited using Holt and Laury (2002) MPL approach influence decision to preserve renewable resources. They find that more risk averse individuals are more likely to support the safe minimum standard preservation choice. Additionally, in the context of CE given the inclusion of a cost variable in choice sets, it does not seem unreasonable to assume that both risk preferences over finance and environment may affect respondents' choices.

The econometric approach we use to jointly analyse our data from the CE and the MPL experiment is based on hybrid choice models, which have been developed over recent years, with key developments by Ben-Akiva et al. (1999, 2002) and Bolduc et al. (2005). This

approach uses latent variables (LVs), which are functions of the socio-demographic variables and an error term, to explain unobserved latent risk preferences. At the same time, in a separate measurement model, these LVs are used to explain answers to follow-up questions, related to psychological constructs included in the model. In our study, the LV represents latent risk preferences.

The key advantage of hybrid choice models is the use of additional data to improve the precision of estimations and to better represent potential heterogeneity, which can be modelled in various ways. The number of applications of hybrid choice models across various fields has increased notably in recent years. Applications in environmental valuation, e.g., have been presented by Hess and Beharry-Borg (2012), Hoyos et al. (2015) or Mariel et al. (2015). Moreover, a recent study that is close to the subject of the present paper uses a LV to incorporate prior outcome beliefs in a stated choice model concerned with investigating how outcome uncertainty affects stated willingness to pay (Lundhede et al. 2015). The authors find that respondent's prior beliefs significantly influence the estimated utility of outcome uncertainty and that the LV model gives valuable insight into the patterns underlying concepts of belief in policy outcome and how they influence the stated willingness to pay for conservation measures.

A methodological novelty of the present study arises from the application of a new approach to link the two parts of the hybrid choice model. We estimate a model that resembles a latent class logit model (LCM) by allowing for the interaction of the LV with a utility coefficient in each class. In previous studies such as Daly et al. (2012) and Glerum et al. (2012), the LV was interacted with attribute coefficients, in Hoyos et al. (2015) the LV was explanatory in a class allocation function of an LCM and Hess and Stathopoulos (2013) used the LV to explain scale heterogeneity within the choice model.

The remainder of paper is organised as follows. Section 2 presents the situation facing lynx in Poland, Section 3 describes the case study and its methodology. Section 4 contains the main results and, finally, Section 5 draws conclusions on the application of the hybrid choice model.

2. The status of lynx populations in Poland

The Eurasian lynx (*Lynx lynx*) is the third largest predator in Europe after the brown bear and the wolf. Poland is one of the few European countries where lynx have survived in the wild. However, the number of Polish lynx living in the wild has decreased to a third over the past 20 years and is estimated to be about 180–200 individuals in total (Jędrzejewski et al., 2002; von Arx et al., 2004). Although lynx have officially been protected in Poland since 1995, little has been done so far to ensure the longer-term survival of the species (Niedziałkowska et al., 2006). In general, their current status in Poland is considered to be ‘near threatened’ according to the IUCN Red List of threatened species.

There are two main lynx populations in Poland: the Lowland population in the northeast and the Carpathian population in the south of the country. Both populations live in border regions and are part of two major populations of this species in Europe. The Polish Carpathian population is larger in number and more widely distributed than the Lowland population and it is estimated to be about 100 animals. Existing migration corridors allow for the exchange of the Carpathian lynx between countries. Meanwhile, the Lowland lynx population, estimated at about 60 animals, occupies a highly fragmented habitat². This group is more isolated from the lynx populations in other countries. These factors contribute to a

² In addition to the Lowland and Carpathian lynx populations and a few isolated individuals in the north of Poland, a group of 12–15 lynx lives in central Poland in the Kampinowski National Park. The group is isolated and cannot survive in the wild without human support.

higher risk of extinction of the Lowland lynx in comparison to the Carpathian population (von Arx et al., 2004).

Niedziałkowska et al. (2006) identified the fragmentation of forest habitats as a major threat for the survival of the lynx populations in Poland. Other threats to the lynx populations occur as a result of current forest management such as the afforestation of open spaces and failing to leave enough deadwood in forests (Schmidt, 2008). Such changes in forests disturb the lynx's hunting and living conditions. Additionally, game hunting and poaching by humans cause food scarcity. If these impacts on habitat conditions continue, it is anticipated that the Polish lynx population may be seriously threatened in the next decades (Niedziałkowska et al., 2006).

3. Survey design and methodology

3.1. Survey structure

The valuation survey consisted of six parts. While in part 1 general information concerning forests in Poland were presented and questions about respondents' recreation patterns in forests were asked, part 2 provided general information on lynx populations in Europe and a detailed description of the two lynx populations in Poland. This information included a physical description of the lynx, its habits, place of occurrence, a current size and status of the Lowland and Carpathian lynx populations and their main threats. Respondent are told that the chances of survival do not depend solely on the population size but other factors such as size of habitat or migration possibilities also influence the Lowland and Carpathian lynx status. Then, Part 3 depicted potential management actions that could increase the chances of survival of the two main lynx populations in the country. Among those actions, the most important is to create corridors and passes across roads and railway tracks enabling the

lynx to migrate between forest complexes. Finally, in Part 4 the choice sets were presented before in part 5 the elicitation of respondents' risk preferences took place through the MPL before the last part requested socio-demographics.

3.2. CE design

The CE comprises three attributes: the status of both the Lowland and the Carpathian lynx population in 20 years from now and the annual cost of the particular conservation programme per person. Following consultation with forest biologists, instead of employing the commonly used increase in the number of individuals as a measure of the improved protection of endangered species, we decided to describe the status of the lynx populations in terms of its chances of survival. The categories used were based on the IUCN Red List of threatened species. To clarify the categories, the official terminology was simplified slightly (see Table 1). Additionally, we informed respondents that the risk of extinction varies from nearly zero, i.e., having a stable population, to close to 100%, i.e., the species is critically threatened. The final category descriptions along with the current and the predicted status for both lynx populations were agreed through consultation with experts from the Institute of Nature Conservation and Mammal Research Institute at the Polish Academy of Sciences.

<Table 1>

For the purposes of the CE, the future status of the Lowland population could take one of five levels (from critically threatened to stable), while for the Carpathian population four attribute levels were used (from highly threatened to stable). The payment vehicle was a tax that would go to a special fund established for lynx conservation in Poland. Table 2 shows the full list of attribute levels in the experimental design.

<Table 2>

The choice sets were created by using a Bayesian S-efficient design with fixed priors gained from responses by focus group participants. An S-efficient design aims at minimising the number of observations necessary to obtain statistically significant parameter estimates (Bliemer and Rose, 2011). The final design comprised 24 choice sets that were blocked into four subsets. Each set comprised two policy options and a business-as-usual option. Each option described the effect the conservation measures would have on the lynx populations' chances of survival in the future. Additionally, the sets provided information about the current number of individuals of each population. To illustrate the differences between the hypothetical threat levels, colours following the idea of traffic lights were used to mark attribute levels. Each attribute level was accompanied by a pictogram of a lynx coloured according to the threat level. Each respondent faced seven choice sets in total, including one with a dominant alternative; the latter choice sets were not used in the present analysis. An example choice set is presented in Figure 1.

<Figure 1>

3.3. Measuring risk preferences with a lottery choice task

Based on the Holt and Laury (2002) approach respondents were presented with a series of 10-paired lotteries. For each of the 10 decisions, they were asked to choose either lottery A or lottery B. In each decision, lottery A was the safe choice and lottery B was the risky option. The payoffs for the safe option were less variable than those for the risky one. For both lotteries, in each successive row, the likelihood of receiving larger rewards increased. For the first four decisions, the expected payoff for lottery A was higher than that for lottery B, while for the next six decisions lottery B had the higher expected payoff. In the last row, no uncertainty was assigned to payoffs. Following Anderson and Mellor (2008), we presented payoffs that were three times higher than the Holt and Laury (2002) baseline

amounts. Table 3 shows the full set of decision tasks. To incentivise respondents, one of the 10 decisions was randomly selected as binding by the roll of a 10-sided dice. Then, a dice was thrown again to determine whether the individual received the high or low real monetary payoff from the chosen lottery.

Table 3. Lottery choice experiment

3.4. Econometric approach

To capture more realistically the choice processes, we incorporated the latent characteristics of decision makers into the model by treating the observed indicators of the latent characteristics as endogenous (Bolduc and Alvarez-Daziano 2010; Yáñez et al. 2010). The hybrid model used in this application was composed of two sets of structural equations and a group of measurement relationships.

The first set of structural equations is represented by the utilities of alternative i for respondent n in the choice occasion t as:

$$U_{int} = V_{int} + \varepsilon_{int} = ASC_i + \beta'x_{int} + \varepsilon_{int}, \tag{1}$$

where V_{int} is a systematic component and ε_{int} is a random variable following an extreme value type I distribution with location parameter 0 and scale parameter 1. The term V_{int} depends on observable explanatory variables, which are usually attributes (x_{int}) and the vector of estimated attribute parameters β . In (1), ASC_i is an alternative specific constant for alternative i normalised to zero for one of the J alternatives.

The standard LCM specification forms the basis of the developments in this paper. Given membership of class c_s , the probability of respondent n 's sequence of choices is given by

$$\Pr(y_n^t | c_s, x_n) = \prod_{t=1}^{T_n} \frac{\exp(ASC_i^{c_s} + \beta'_{c_s} x_{int})}{\sum_{j=1}^J \exp(ASC_i^{c_s} + \beta'_{c_s} x_{jnt})}, \quad (2)$$

where y_n^t is the sequence of choices over the T_n choice occasions for respondent n . Equation (2) is a product of MNL probabilities. If the probability of membership to an LC c_s of respondent n is defined as π_{n,c_s} , the unconditional probability of a sequence of choices can be derived by taking the expectation over all C classes, that is

$$P_n = \Pr(y_n^t | x_n) = \sum_{s=1}^C \pi_{n,c_s} \prod_{t=1}^{T_n} \frac{\exp(ASC_i + \beta'_{c_s} x_{int})}{\sum_{j=1}^J \exp(ASC_i + \beta'_{c_s} x_{jnt})}. \quad (3)$$

The class allocation probabilities π_{n,c_s} are usually modelled by using a logit structure, where the utility of a class is a function of a constant $\mu_{0,s}$, the socio-demographics of the respondent (SD_n) and corresponding parameters (λ_s), that is

$$\pi_{n,c_s} = \frac{\exp(\mu_{0,s} + \lambda'_s SD_n)}{\sum_{s=1}^C \exp(\mu_{0,s} + \lambda'_s SD_n)}. \quad (4)$$

The additional constant $\mu_{0,s}$ and parameters λ are fixed to zero for one of the classes for normalisation reasons.

As the next step, we used the answers provided by respondents to the lottery choices reported in Table 3. These answers are, together with respondents' choices in the CE, driven by underlying risk preferences; nevertheless, they are not direct measures of them. The latent risk preferences are therefore treated as LVs and the lottery choices are used as indicators in the model. The structural equation for the LV is given by

$$LV_n = \gamma_1 Z_{1n} + \gamma_2 Z_{2n} + \dots + \gamma_m Z_{mn} + \omega_n, \quad (5)$$

where $Z_{1n}, Z_{2n}, \dots, Z_{mn}$ are the specific socio-demographic variables and ω_n is a random disturbance that is assumed to be normally distributed with a zero mean and standard deviation σ_ω .

The measurement equations use the lottery choices as dependent variables, and therefore as indicators of individuals' risk aversion. The ℓ^{th} indicator of all L indicators (in our case, $L = 9$ as in the last 10th lottery, lottery B was chosen by all individuals) for respondent n is defined as

$$I_{\ell n} = m(LV_n, \zeta) + v_n, \quad (6)$$

where the indicator $I_{\ell n}$ is a function of LV_n and a vector of parameters ζ . The responses to the lottery choice are binary; therefore, the measurement equation for individual n is modelled as a binary logit model for the LV:

$$I_{\ell n} = \begin{cases} 0 & \text{if } -\infty < LV_n \leq \tau_{\ell} \\ 1 & \text{if } \tau_{\ell} < LV_n \leq \infty \end{cases}, \quad (7)$$

where τ_{ℓ} are the thresholds that need to be estimated. The likelihood of a specific observed value of $I_{\ell n}$ is then given by

$$L_{I_{\ell n}} = I_{(I_{\ell n}=0)} \left[\frac{\exp(\tau_{\ell} - \zeta_{\ell} LV_n)}{1 + \exp(\tau_{\ell} - \zeta_{\ell} LV_n)} \right] + I_{(I_{\ell n}=1)} \left[1 - \frac{\exp(\tau_{\ell} - \zeta_{\ell} LV_n)}{1 + \exp(\tau_{\ell} - \zeta_{\ell} LV_n)} \right], \quad (8)$$

where ζ_{ℓ} measures the impact of LV_n in indicator $I_{\ell n}$ and τ_{ℓ} is estimated as the threshold parameter. In the present study, we used a novel approach to link the two parts of the model. We estimated an LCM and allowed interaction of the LV defined in (5) with the alternative specific constant of the business-as-usual option (ASC_{SQ}) in each class in order to analyse the effect of the LV on the riskiest alternative in terms of the survival of both lynx populations.

The terms V_{int} of (1) corresponding to class c_s are defined as

$$V_{1nt}^{c_s} = (ASC_{SQ}^{c_s} + \delta^{c_s} LV_n) + \beta_{Carpa}^{c_s} Carpa_{1nt} + \beta_{Lowland}^{c_s} Lowland_{1nt} + \beta_{Cost}^{c_s} Cost_{1nt} \quad (9)$$

$$V_{2nt}^{c_s} = ASC_2^{c_s} + \beta_{Carpa}^{c_s} Carpa_{2nt} + \beta_{Lowland}^{c_s} Lowland_{2nt} + \beta_{Cost}^{c_s} Cost_{2nt}$$

$$V_{3nt}^{c_s} = \beta_{Carpa}^{c_s} Carpa_{3nt} + \beta_{Lowland}^{c_s} Lowland_{3nt} + \beta_{Cost}^{c_s} Cost_{3nt}$$

where *Carpa*, *Lowland* and *Cost* are the choice attributes described in Table 2, δ is the parameter corresponding to the LV, which is added to the constant term in the business-as-usual option, and β are the class-specific attribute parameters.

The estimation of the model involves maximising the joint likelihood of the observed sequence of choices and observed answers to the lottery choices. The two components are conditional on the given realisation of LV_n . Accordingly, the log-likelihood function of the model is given by integration over ω_n

$$LL(\beta, \mu, \gamma, \mu, \zeta, \tau) = \sum_{n=1}^N \ln \int_{\omega} (P_n \prod_{\ell=1}^9 L_{I_{\ell n}}) g(\omega) d\omega, \quad (10)$$

where P_n is defined in (3), with class allocation probabilities π_{n,c_s} defined in (4), $L_{I_{\ell n}}$ is defined in (8) for $\ell = 1, 2, \dots, 9$. The joint likelihood function (10) depends on the parameters of the utility functions $\beta = (ASC_1^{C_s}, ASC_2^{C_s}, \beta_{Carpa}^{C_s}, \beta_{Lowland}^{C_s}, \beta_{Cost}^{C_s})$, the parameters $\mu = (\mu_{0,s})$ and $(\lambda_1^s, \lambda_2^s, \dots, \lambda_K^s)$ contain the parameters used in the allocation probabilities defined in (4), $\gamma = (\gamma_0, \gamma_1, \gamma_2, \dots, \gamma_m)$ contain the parameters for the socio-demographic interactions in the LV specification defined in (5), and $\zeta = (\zeta_1, \zeta_2, \dots, \zeta_{10})$ and $\tau = (\tau_1, \tau_2, \dots, \tau_{10})$ contain the parameters defined in (6) and (7). We follow the Bolduc normalisation by setting $\sigma_{\omega} = 1$. All model components were estimated simultaneously by using PythonBiogeme (Bierlaire, 2003, 2008).

3.5. Data

The sample of respondents was drawn from Warsaw inhabitants. Ours was a quota sample representative of the Warsaw population in terms of gender, age and education. The survey was carried out in February 2011. Interviews were conducted by a professional polling agency by using the computer-assisted personal interviewing system. In total, 300

questionnaires were collected. The main survey was pretested in 50 face-to-face interviews with students from the Faculty of Economics at the University of Warsaw.

<Table 4>

Individuals were excluded from the analysis if they chose the safe option for decision 10 in the lottery experiment or if they switched constantly between lottery A and lottery B for all 10 decisions. The literature shows that generally a certain share of respondents does not understand the design of the lottery, i.e., the changes in the probabilities of the outcomes in lottery A and lottery B. These respondents are thus excluded from further analysis. Additionally, respondents who always chose the most expensive alternative in the CE part were omitted. We assumed that these individuals were protesting against some aspect of the survey. This resulted in a final set of responses from 214 individuals corresponding to 1,284 observations to be analysed.

4. Results

4.1 Risk preference elicitation

Of the analysed sample, 69% of respondents started with lottery A, then switched from this option to lottery B just once and played this lottery thereafter. On the contrary, 31% switched back from the risky lottery B to lottery A. Holt and Laury (2002), Lusk and Coble (2005) and Anderson and Mellor (2008) also report this kind of behaviour in their lottery experiments, but the share of multiple switchers in their cases is lower (13%, 5% and 21%, respectively). However, the first two surveys were conducted solely among students, while only the Anderson and Mellor sample comprised mostly non-student adults. In the present survey, respondents were recruited from the general public. This might explain why we

observe a larger share of respondents who switch back as it could be expected in a sample with students, e.g. Table 5 shows the share of “safe” choices (lottery A) in the sample.

<Table 5>

4.2 Hybrid latent class model results

Similar to a standard LCM framework, the first task when specifying a hybrid latent class model (HLCM) is to determine the number of classes. Table 6 reports LCM as well as HLCM’s goodness-of-fit indicators together with the number of parameters. As expected, the log-likelihood decreases as the number of classes increases. For the HLCM, the BIC and CAIC indicate a solution with three classes, while the AIC favours models with four classes. However, the AIC tends to overestimate the number of classes and, moreover, there is consensus in the literature that parsimony is preferable in modelling, especially in this complicated hybrid framework. For the LCM, the three class model is the preferred option indicated by the three indicators. Therefore, we choose the LCM with three classes for further analysis.

<Table 6>

Table 7 presents the estimations of the plain and the hybrid LCM. As expected, there is little difference in the parameter estimates between these two estimations. The hybrid model uses additional information for the estimation of the choice part model, which allows for a richer interpretation. The *Cost* coefficient in all three classes and two attribute parameters indicating an improvement in lynx protection are significant at a level of 5% with the expected positive sign in the second and third classes. Respondents in these two classes would be better off if conservation measures leading to better lynx conservation were

implemented, but at different costs. However, lynx conservation attributes are not significant in the first class.

<Table 7>

The estimation of the allocation model of the plain LCM (Table 8) showed no significant socio-demographics. However, in the HLCM, apart from the constant variable, age was also significant in the allocation function of class 3. The corresponding class probabilities computed according to (4) are presented in Table 7. The highest probability is assigned to class 3 in the two estimated models.

<Table 8>

Table 9 presents estimation results of the structural and measurement equations and confirms that the latent risk preferences influence respondents' decision processes as the impact of the LVs on the lottery choices was clearly significant for all nine latent risk preference indicators (ζ). Only household income of the four socio-demographic variables included in the set of structural equations is significant (9), indicating that people with higher household incomes have higher values of the LVs³.

According to (7), a higher value of LV_n implies a lower probability of choosing the safer lottery A (because the term $\tau_\ell - \zeta_\ell LV_n$ becomes lower) but a higher probability of choosing the riskier lottery B. This result, therefore, indicates that respondents with higher household incomes are more risk seeking than respondents with lower incomes. On the contrary, for a given value of LV_n , the gradual decrease in the parameters ζ_ℓ and τ_ℓ for the sequence of lotteries 1–9 (Table 9) indicates a decrease in the probability of choosing the safer lottery A for the benefit of the riskier choice of lottery B. This finding is in accordance with the expected payoffs presented in Table 3.

³ A low number of significant socio-demographics is a typical characteristic of hybrid choice models (Daly et al., 2012).

The parameter δ corresponding to the LV added to the constant term in the SQ alternative (8) is significant at 5% in two of the three classes (Table 7). In the first class, its effect is positive and negative in the second. Individuals with a high value for these constants are more likely to choose (for the lynx population) the riskier SQ option. In other words, the LV clearly affects respondents' choices and therefore their WTP measures. The LV can interact with the choice model in many different ways. For example, it can influence the attribute coefficients in (1) or it can be an explanatory in allocation probabilities (4). The estimation of these alternative specifications led however to non-significant interaction and that is why only the effect on SQ constant was finally included.

<Table 9>

In the next step, WTP measures were computed from the HLCM estimates, giving the implied monetary valuation of different changes in attribute levels. These values are probability-weighted WTP values corresponding to the parameters presented in Table 7. That is, e.g., for the Carpathian population, the individual WTP values are computed as:

$$WTP = \pi_{n,c_1} \left(-\frac{\beta_{Carp}^{c_1}}{\beta_{Cost}^{c_1}} \right) + \pi_{n,c_2} \left(-\frac{\beta_{Carp}^{c_2}}{\beta_{Cost}^{c_2}} \right) + \pi_{n,c_3} \left(-\frac{\beta_{Carp}^{c_3}}{\beta_{Cost}^{c_3}} \right) \quad (11)$$

Table 10 shows, for the sample population of respondents, the distribution of the WTP values based on the plain LCM and the HLCM for both lynx populations. It also presents the WTP values computed by using the posterior estimate of the LC probabilities defined as:

$$\hat{\pi}_{c_s|n} = \frac{\hat{P}_{n|c_s} \hat{\pi}_{n,c_s}}{\sum_{s=1}^C \hat{P}_{n|c_s} \hat{\pi}_{n,c_s}}, \quad (12)$$

where $\hat{P}_{n|c_s}$ represents, for the given class assignment, the contribution of individual n to the likelihood through the joint probability of the sequence defined as:

$$\hat{P}_{n|c_s} = \prod_{t=1}^{T_n} \frac{\exp(\widehat{ASC}_i^{c_s} + \hat{\beta}'_{c_s} x_{int})}{\sum_{j=1}^J \exp(\widehat{ASC}_i^{c_s} + \hat{\beta}'_{c_s} x_{jnt})} \quad (13)$$

According to the definition of the utility function (8), the constant ($ASC_i^{c_s}$) for the business-as-usual option is respondent-specific and a function of LV_n , which at the same time depends on one socio-demographic variable (household income) and a random error term (5), meaning that the constant follows a random distribution. In order to compute the posterior estimate of the LC probabilities, we simulate the constant corresponding to the business-as-usual option according to (5) and (9) by using 10,000 draws for the LV of each respondent, combining the estimated parameter $\gamma_{Householdincome}$ with the corresponding values of the variable household income and adding generated random errors ω .

<Table 10>

As shown in Table 10, the posterior LC probabilities increase the spread of the two distributions and shift them slightly to the right. The WTP for the Lowland population is higher than that for the Carpathian population, suggesting that people prefer to invest more in conservation programmes that protect the population at a higher risk of extinction.

Table 11 presents the same WTP values corresponding to the HLCM and based on the posterior LC probabilities. The structure of the HLCM and the two relevant socio-demographic variables in (4) and (5) allow to simulate the WTPs for four subgroups characterised by different age and household income levels. Individuals assigned to the low

(high) household income group are those with a household income lower than the 25th (higher than the 75th) percentile. Similarly, assignment to the younger and older age groups is based on the 25th and 75th percentiles of the variable age.

<Table 11>

The results show that older people are less willing to invest in the 20-year protection programme than younger people. On the contrary, people with a higher household income are willing to pay more than people with a low household income. An interesting result is that the differences in WTP distributions are much higher between younger and older people than between people with low and high household incomes. This finding means that people are aware of the risk of lynx extinction in Poland and are willing to invest in conservation programmes; nevertheless, their WTP increases slowly with household income but decreases rapidly with age.

The two competing models presented in Table 7 and 8 show very similar parameters estimation and, subsequently, very similar WTP values (Table 10). A comparison of their goodness of fit is however not straightforward and there is still on-going debate regarding the added value of hybrid models. Seeking an alternative fit comparison we computed the predicted probabilities for the two models. Afterwards we generated 1000 uniform random numbers between 0 and 1 for each individual and simulated his/her predicted outcome. Table 11 presents the classification table of observed and predicted outcomes for the plain LCM and the HLCM. The Count R^2 defined as percentage of correct predictions located on the diagonal cells of the two matrices in Table 11 is and 42.5% for the LCM and 41.3% for the HLCM 1. Thus, similar to the estimation results, the predictions of the two models are very similar.

5. Conclusions and discussion

This paper extends our knowledge about the association between individual risk preferences and investments in an environmental good with uncertain results. As far as we are aware of the literature the study has introduced two new elements. Firstly, the use of an incentivized multiple price list to elicit risk preferences and, secondly, the application of a latent variable model to link the responses to a lottery and to a choice experiment. Using this approach we analysed the role that latent risk preferences may play in people's preferences towards lynx protection in Poland.

The results show that individuals' latent risk preferences are significantly related to the constant of the business-as-usual option, i.e. the option without additional conservation measures and a zero-price, influencing, therefore, the probability that it will be chosen. It is also noteworthy that the incorporated LV is significantly related to the variable household income. This finding is in line with other findings in the literature, suggesting that risk preferences may be correlated with wealth (e.g. Rosenzweig and Binswanger 1993; Liu 2013)⁴. At the same time, the LV provides a strong explanation of respondents' choices in the series of nine lotteries. The results thus confirm the findings from other studies indicating that respondents' choices are, apart from the attributes of the alternatives, related to their latent risk preferences.

Our findings also indicate that the choice of the business-as-usual option may be linked to fundamental risk preferences, even if exacerbated by psychological influences such as framing or anchoring effects (Tversky and Kahneman 1974). Often, in CEs regarding conservation policies, the business-as-usual option without further measures is the riskiest of the presented alternatives because not carrying out additional measures increases the likelihood that populations become extinct. The other alternatives are usually programmes aimed at improving the current environmental situation. Therefore, it may be prudent to elicit

⁴ However, the literature on whether risk preferences vary with wealth level is inconclusive (see Cardenas and Carpenter, 2008).

individual risk preferences as a possible explanatory variable in order to estimate the impact on estimated WTP.

The methodological novelty of this study arises from developing a new approach to linking the LVs to the choice model part. We estimate the hybrid model, which resembles an LCM but allows for the interaction of the LV with an attribute (in this case, the ASC of the business-as-usual option) in each class. The comparison of the plain LCM and HLCM questions the usefulness of the more complicated approach based on latent variables. As already stated in the literature, hybrid models gain in efficiency by the inclusion of additional information, e.g., attitudinal questions in the choice model. If we compare the performance of our two models, both perform very similarly and no big differences can be found between the estimated parameters and the prediction outcomes. However, the methodologically advanced hybrid model presented in this application shows complex forms of inter-variable relations and how they relate to preference heterogeneity. Overall, our findings, i.e., similar parameter estimates, similar model fit and narrower WTP spread, support the conclusion of Kløjgaard and Hess (2014) and Dekker et al. (2013) who point out that advanced hybrid choice models do not result in different key findings compared to standard approaches, despite a greater insight into attitudes as drivers of choices as well as some gains in efficiency. Nevertheless, the outstanding feature of the HLCM in our study is the link of the stated WTP to the socio-demographic variables not found in the plain LCM. That the marginal WTP estimates found in the LV model do not significantly differ from those derived from a rather standard modelling approach is also reported by Lundhede et al. (2015). They furthermore support our finding that the LV model gives valuable insights into the patterns underlying the stated choices. Regarding the provided insight it is noteworthy that Lundhede et al. (2015) also found a significant influence of age on the latent variable and subsequently on a lower willingness to pay of older people.

Overall, based on the results we believe that employing a choice experiment and a lottery in the same survey is a promising combination. Various issues, however, remain and need to be addressed in future studies. Holt and Laury (2002) MPL, e.g., was designed to capture risk preferences in the financial domain. While it has been shown in the literature that risk preferences elicited using this approach are also meaningful in other domains, e.g. for predicting health behaviours (Andersen and Mellor, 2010), lotteries aiming directly at environmental risks might be more suitable as a determinant of choices among alternatives with uncertain environmental outcomes. Finally, the application of the LV approach is still new to environmental valuation, especially regarding uncertainties of conservation policies. In line with the study by Lundhede et al. (2015) the results indicate that these models give richer insights into what determines choice among the offered alternatives. To what extent this finding can be generalized has to be answered by future studies.

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For Peer Review

Table 1. Levels of threat.

IUCN Red List	Scale adapted for the CE
Critically Endangered - Extremely high risk of extinction in the wild.	Critically threatened - Extremely high risk of extinction in the wild
Endangered - High risk of extinction in the wild.	Highly threatened - High risk of extinction in the wild.
Vulnerable - High risk of endangerment in the wild.	Moderately threatened - Moderate risk of extinction in the wild.
Near Threatened - Likely to become endangered in the near future.	Low threat level - Low risk of extinction in the wild.
Least Concern - Lowest risk. Does not qualify for a more at risk category.	Stable - Negligible risk of extinction in the wild.

Note: The IUCN Red List includes two additional categories: extinct in the wild and extinct, which were not included in the valuation survey, as they were not seen to be necessary for the purpose of our study.

Table 2. Attributes and levels in the CE.

Attributes	Levels [Coding]
Lowland lynx population (<i>Lowland</i>)	critically threatened [5] (expected for business-as-usual, i.e., without additional protection measures), highly threatened [4], moderately threatened [3], low threat level [2], stable [1]
Carpathian lynx population (<i>Carpa</i>)	highly threatened [4] (expected for business-as-usual), moderately threatened [3], low threat level [2], stable [1]
Cost per person per year (<i>Cost</i>)	0 zł (business-as-usual), 15 zł, 50 zł, 90 zł, 150 zł

Note: The nominal exchange rate from February 2011: 1 € = 3.9 zł.

Table 3. Lottery choice experiment.

Decision	Lottery A	Lottery B	E(A) –E(B)
1	Receive 18zl if dice throw is 1 . Receive 14.50zl if dice throw is 2-10 .	Receive 34.70zl if dice throw is 1 . Receive 0.90zl if dice throw is 2-10 .	10.6
2	Receive 18zl if dice throw is 1-2 . Receive 14.50zl if dice throw is 3-10 .	Receive 34.70zl if dice throw is 1-2 . Receive 0.90zl if dice throw is 3-10 .	7.5
3	Receive 18zl if dice throw is 1-3 . Receive 14.50zl if dice throw is 4-10 .	Receive 34.70zl if dice throw is 1-3 . Receive 0.90zl if dice throw is 4-10 .	4.5
4	Receive 18zl if dice throw is 1-4 . Receive 14.50zl if dice throw is 5-10 .	Receive 34.70zl if dice throw is 1-4 . Receive 0.90zl if dice throw is 5-10 .	1.5
5	Receive 18zl if dice throw is 1-5 . Receive 14.50zl if dice throw is 6-10 .	Receive 34.70zl if dice throw is 1-5 . Receive 0.90zl if dice throw is 6-10 .	-1.6
6	Receive 18zl if dice throw is 1-6 . Receive 14.50zl if dice throw is 7-10 .	Receive 34.70zl if dice throw is 1-6 . Receive 0.90zl if dice throw is 7-10 .	-4.6
7	Receive 18zl if dice throw is 1-7 . Receive 14.50zl if dice throw is 8-10 .	Receive 34.70zl if dice throw is 1-7 . Receive 0.90zl if dice throw is 8-10 .	-7.6
8	Receive 18zl if dice throw is 1-8 . Receive 14.50zl if dice throw is 9-10 .	Receive 34.70zl if dice throw is 1-8 . Receive 0.90zl if dice throw is 9-10 .	-10.6
9	Receive 18zl if dice throw is 1-9 . Receive 14.50zl if dice throw is 10 .	Receive 34.70zl if dice throw is 1-9 . Receive 0.90zl if dice throw is 10 .	-13.7
10	Receive 18zl if dice throw is 1-10 .	Receive 34.70zl if dice throw is 1-10 .	-16.7

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Table 4. Descriptive statistics of the analysed sample.

	Share	Mean	Median	Min	Max
Women	53%				
Age		46	47	20	90
Education					
- Primary	8%				
- Secondary	49%				
- High	43%				
Net monthly household income in zł		4,359	3,500	500	22,500

Table 5. Responses to the lottery.

Decision	Share of “safe” choices (Lottery A)
Row 1	75%
Row 2	64%
Row 3	74%
Row 4	60%
Row 5	59%
Row 6	36%
Row 7	41%
Row 8	29%
Row 9	31%

Table 6. Goodness-of-fit criteria for different numbers of classes.

	LCM			HLCM		
	<i>2 Classes</i>	<i>3 Classes</i>	<i>4 Classes</i>	<i>2 Classes</i>	<i>3 Classes</i>	<i>4 Classes</i>
LogL	-926.4	-862.7	-854.6	-1850.9	-1796.0	-1776.5
Number of parameters	15	25	35	39	50	61
Sample size	1284	1284	1284	1284	1284	1284
AIC	1882.9	1775.3	1779.2	3779.8	3692.0	3675.0
BIC	1960.2	1904.3	1959.7	3981.0	3949.9	3989.6
CAIC	1975.2	1929.3	1994.7	4020.0	3999.9	4050.6

Table 7. Estimation results: choice model component.

LCM									
	Class 1		Class 2		Class 3				
Class prob.	0.06		0.06		0.88				
	Est.	rob. t-rat.	Est.	rob. t-rat.	Est.	rob. t-rat.			
ASC SQ	0.577	0.60	-3.12	***	-8.41	-1.920	***	-4.21	
ASC A	-0.873	-1.18	0.47	*	1.85	7.720		0.86	
Carpathian	0.045	0.16	0.375	**	2.20	0.455	***	5.03	
Lowland	-0.367	-1.18	0.271	**	2.47	0.660	***	7.57	
Cost	-0.016	*	-1.94	-0.035	***	-5.69	-0.003	***	-2.61
HLCM									
	Class 1		Class 2		Class 3				
Class prob.	0.17		0.17		0.66				
(median)									
(25th, 75th percentile)	(0.14,0.23)		(0.14,0.23)		(0.53,0.72)				
	Est.	rob. t-rat.	Est.	rob. t-rat.	Est.	rob. t-rat.			
ASC SQ	-11.900	*	-1.93	-4.010	***	-3.93	-1.640	***	-3.25
δ (LV coeff.)	15.200	**	2.30	-3.270	***	-3.48	0.401		0.92
ASC A	0.546		1.40	-0.057		-0.14	0.066		0.59
Carpathian	-0.038		-0.12	0.520	*	1.92	0.531	***	4.36
Lowland	0.103		0.48	0.251	*	1.65	0.705	***	6.54
Cost	-0.015	**	-2.02	-0.049	***	-3.11	-0.004	**	-2.39

Table 8. Estimation results: Probability allocation functions.

LCM					
<i>Class 2</i>	Est.	rob. t-rat.	<i>Class 3</i>	Est.	rob. t-rat.
$\mu_{0,2}$	1.610	1.32	$\mu_{0,3}$	2.760 **	2.53
$\lambda_{Age,2}$	0.018	0.10	$\lambda_{Age,3}$	-0.112	-0.69
$\lambda_{Female,2}$	-0.432	-0.77	$\lambda_{Female,3}$	-0.250	-0.47
$\lambda_{Householdincome,2}$	0.271	0.20	$\lambda_{Householdincome,3}$	0.190	0.14
$\lambda_{University,2}$	-0.016	-0.02	$\lambda_{University,3}$	-0.470	-0.80
HLCM					
<i>Class 2</i>	Est.	rob. t-rat.	<i>Class 3</i>	Est.	rob. t-rat.
$\mu_{0,2}$	1.490	1.25	$\mu_{0,3}$	2.470 **	2.43
$\lambda_{Age,2}$	-0.219	-1.08	$\lambda_{Age,3}$	-0.277 *	-1.70
$\lambda_{Female,2}$	-0.078	-0.11	$\lambda_{Female,3}$	0.078	0.14
$\lambda_{Householdincome,2}$	-0.649	-0.74	$\lambda_{Householdincome,3}$	-0.212	-0.32
$\lambda_{University,2}$	-0.040	-0.06	$\lambda_{University,3}$	-0.572	-0.99

Table 9. Estimation results: structural and measurement equations.

<i>Structural equation</i>							
	Est.	rob. t-rat.					
γ_{Age}	0.010	0.18					
γ_{Female}	-0.198	-0.86					
$\gamma_{Householdincome}$	0.435 **	3.47					
$\gamma_{University}$	-0.056	-0.35					
<i>Measurement equations</i>							
	Est.	rob. t-rat.		Est.	rob. t-rat.		
τ_1	3.42 **	2.52	ζ_1	4.36 ***	4.02		
τ_2	1.55 *	1.79	ζ_2	3.34 ***	3.34		
τ_3	2.43 ***	2.78	ζ_3	2.90 ***	4.08		
τ_4	1.33	1.42	ζ_4	3.20 ***	2.74		
τ_5	0.94	1.28	ζ_5	2.78 ***	5.12		
τ_6	-0.65	-0.97	ζ_6	2.48 ***	4.31		
τ_7	-0.38	-0.84	ζ_7	1.68 ***	3.97		
τ_8	-1.14 **	-2.21	ζ_8	1.81 ***	3.92		
τ_9	-0.95 ***	-2.63	ζ_9	1.24 ***	3.71		

Table 10. Marginal WTP in zł.

HLCM			
	25th percentile	Median	75th percentile
<i>Using prior probabilities</i>			
Carpathian	69.1 zł	75.2 zł	83.1 zł
Lowland	92.8 zł	100.3 zł	111.5 zł
<i>Using posterior probabilities</i>			
Carpathian	28.5 zł	129.9 zł	137.8 zł
Lowland	34.9 zł	172.7 zł	183.0 zł
LCM			
	25th percentile	Median	75th percentile
<i>Using prior probabilities</i>			
Carpathian	71.5 zł	76.0 zł	81.6 zł
Lowland	98.5 zł	105.3 zł	113.8 zł
<i>Using posterior probabilities</i>			
Carpathian	14.2 zł	100.7 zł	129.9 zł
Lowland	13.1 zł	144.2 zł	188.3 zł

Table 11. Distribution of the marginal WTP in zł for different subgroups.







Younger people						
	<i>Low household income</i>			<i>High household income</i>		
	<i>25th percentile</i>	<i>Median</i>	<i>75th percentile</i>	<i>25th percentile</i>	<i>Median</i>	<i>75th percentile</i>
Carpathian	50.1 zł	134.1 zł	137.8 zł	63.0 zł	136.6 zł	137.9 zł
Lowland	67.1 zł	178.1 zł	182.1 zł	81.2 zł	181.4 zł	183.1 zł
Older people						
	<i>Low household income</i>			<i>High household income</i>		
	<i>25th percentile</i>	<i>Median</i>	<i>75th percentile</i>	<i>25th percentile</i>	<i>Median</i>	<i>75th percentile</i>
Carpathian	19.4 zł	127.7 zł	137.7 zł	26.0 zł	124.1 zł	137.8 zł
Lowland	25.7 zł	170.2 zł	182.9 zł	31.02 zł	164.5 zł	183.0 zł

Table 12. Classification tables of observed and predicted outcomes for LC and HLC

Models.

HLCM					LCM				
<i>Predicted</i>					<i>Predicted</i>				
<i>Observed</i>					<i>Observed</i>				
<i>1</i>					<i>1</i>				
<i>2</i>					<i>2</i>				
<i>3</i>					<i>3</i>				
2.7%	2.8%	4.0%			2.3%	2.1%	5.1%		
9.8%	17.5%	22.6%			6.5%	13.6%	29.8%		
7.5%	17.5%	21.1%			4.8%	13.6%	26.6%		
Count R ²	41.3%				Count R ²	42.5%			

Figure 1. Example choice set

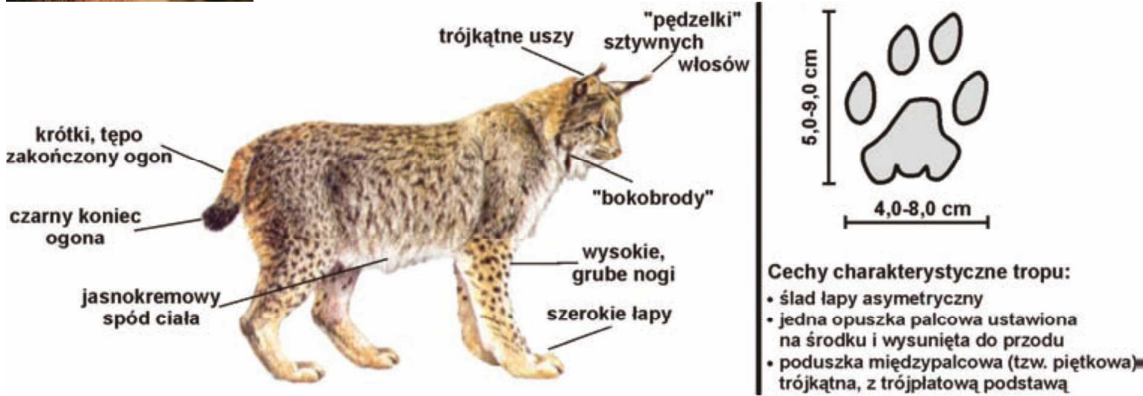
	Programme A	Programme B	Programme C
	<u>No additional protection measures</u>	<u>Additional protection measures</u>	<u>Additional protection measures</u>
	Expected results in 20 years	Expected results in 20 years	Expected results in 20 years
LOWLAND LYNX POPULATION Current number: <u>60 animals</u>	CRITICALLY THREATENED Extremely high risk of extinction 	STABLE POPULATION Negligible risk of extinction 	CRITICALLY THREATENED Extremely high risk of extinction 
CARPATHIAN LYNX POPULATION Current number: <u>100 animals</u>	HIGHLY THREATENED High risk of extinction 	HIGHLY THREATENED High risk of extinction 	MODERATELY THREATENED Moderate risk of extinction 
Cost per person per year	0 zł	90 zł	90 zł
I prefer the most	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

INFORMATION GIVEN TO RESPONDENTS REGARDING THE LYNX AND OUTCOME UNCERTAINTY

Forests in Poland are a place to live for many common species of animals including deer, roe-deer, wild boars, foxes and hares. However, Polish forests are also home to species whose populations are less numerous, and which, without adequate protection are threatened with extinction. Examples of these are: bison, bears, wolves, beavers and lynx. In the remainder of the survey we would like to focus on the lynx population in Poland.

The Lynx is the largest feline representative in Europe. The average length of an adult lynx is about one meter and its average weight 20 kg. It has red fur with black or brown spots. Its ears are characteristically tufty.

INTERVIEWER: Show pictures



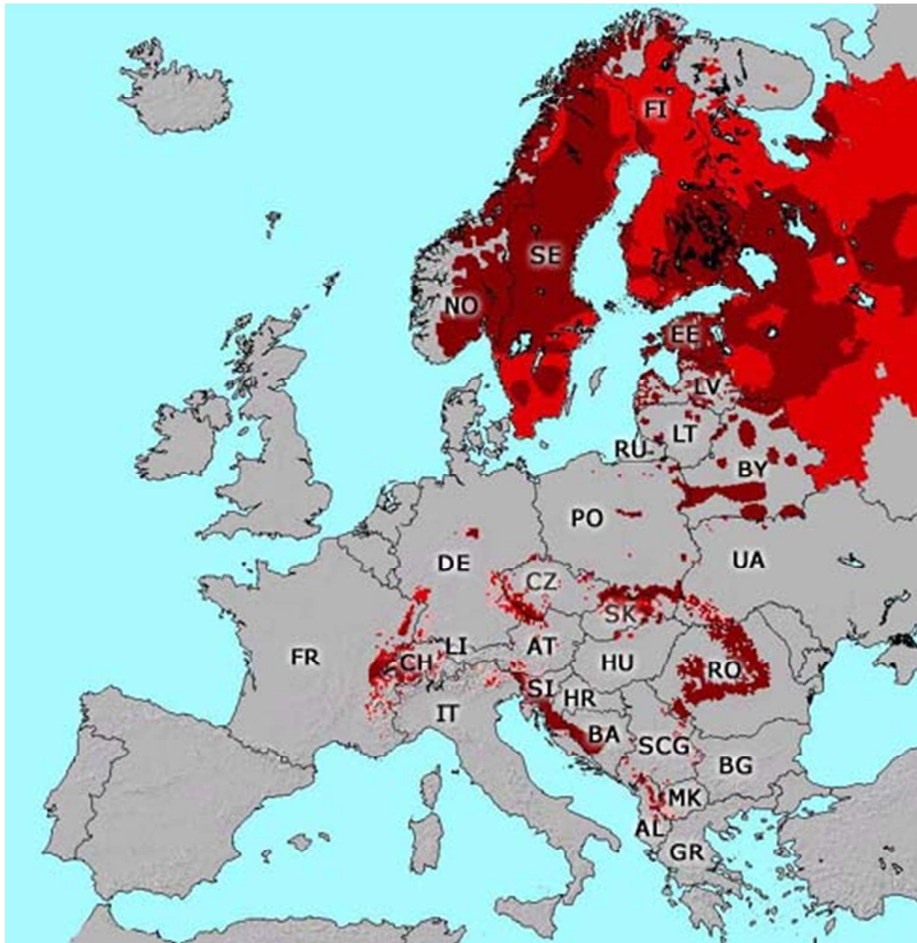
Źródło: Biblioteka monitoringu środowiska. 1361 Ryś euroazjatycki.

Lynx live only in the **large wooded areas**. They are very reluctant to cross large open areas. They prey mainly on deer and roe-deer. In extremely rare cases, a lynx will kill domestic animals (mainly sheep). They are **not dangerous to people** and avoid them whenever possible. They are active mainly at night. Lynx. To meet a lynx in the wild is almost impossible.

Poland is one of the few European countries where the populations of lynx survive in the wild. Due to the geographical location, Poland links areas of eastern Europe, where there are still compact and dense populations of these animals, and the forested areas of Western Europe, where lynx were

extinct. In some of Western European countries the process of reintroduction of the lynx has started. This means restoring wild populations in forests.

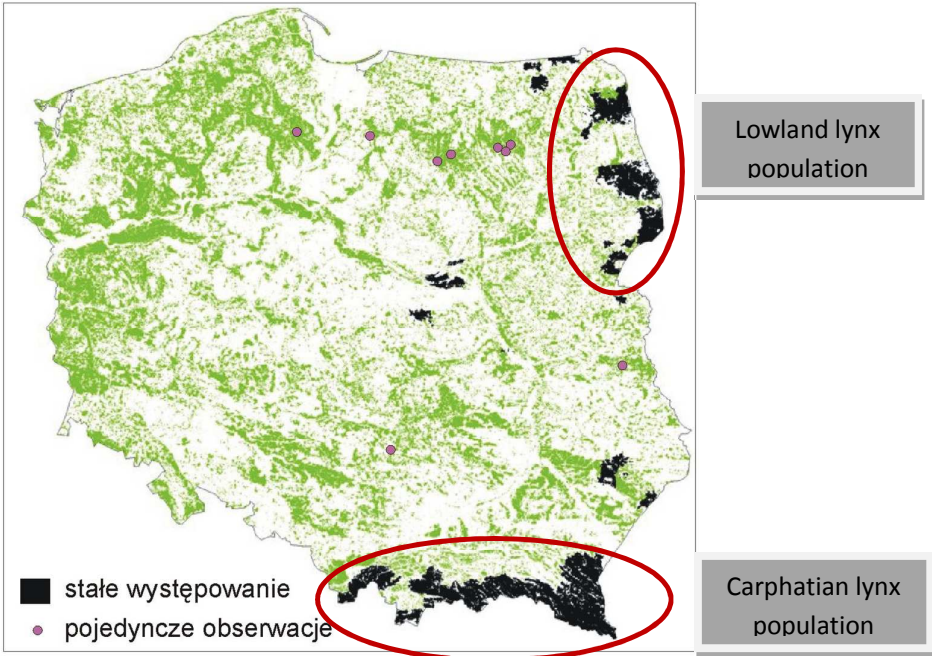
INTERVIEWER: Show a map 1. **Lynx distribution in Europe**



Źródło: Lynx survey Europe 2001.

In Poland, the number of lynx living in the wild has fallen dramatically over the last 20 years. Now there are about **180-200 lynx**. This low number of lynx and their restricted distribution led to their inclusion in 1995 on the list of protected animals in Poland. They live mainly in two regions: in the **north-east** part of Poland and the **Carpathian** region.

INTERVIEWER: Show map 2. Lynx distribution in Poland



Źródło: Schidt i In. 2006

In future, the lynx faces extinction on Polish territory. Although the lynx has been listed as a protected species in Poland since 1995, in practice, little has been done so far to ensure its survival apart from a ban on hunting.

The biggest problems for conserving the Lynx are:

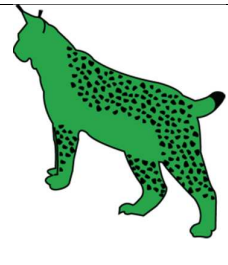
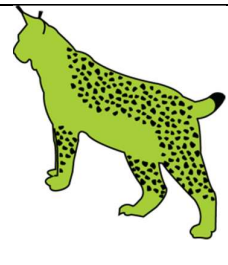
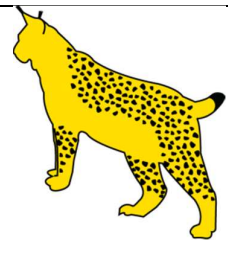
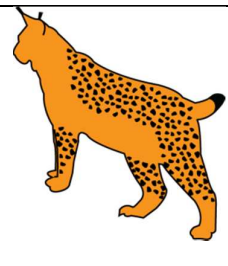
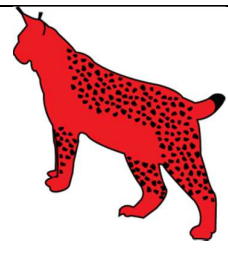
- **fragmentation of forests**
- **insufficient prey,**
- **poor forest undergrowth and an insufficient amount of deadwood, which influence conditions for rest and hunting,**
- **and poaching.**

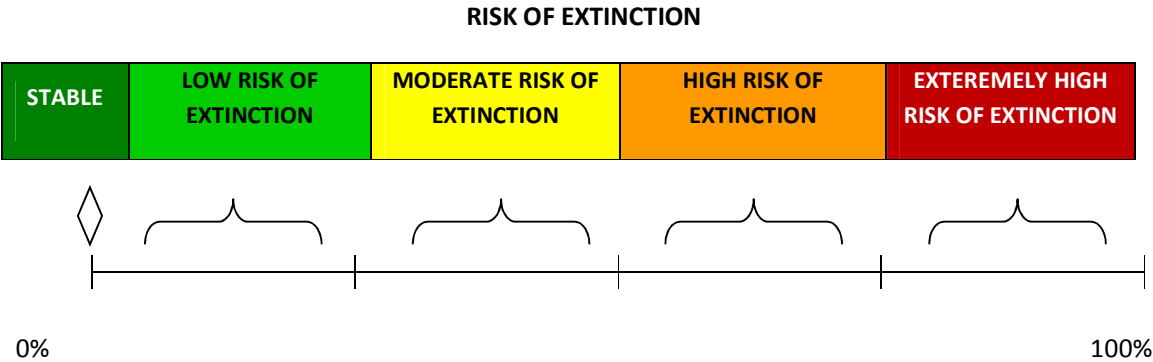
Populations of animals at risk can be attributed to several categories depending on how scientists assess their chances of survival in the wild. This ranges from animals whose chances of **survival are almost certain**, to animals, which will be **almost certainly extinct** if natural conditions remain unchanged. Since the assessment of survival of the species refers to the future, it is fraught with uncertainties and it is difficult to be very precise.

In terms of the chances of survival, lynx populations can be divided into:

INTERVIEWER: Show CARD 1

POPULATIONS

	<ul style="list-style-type: none"> STABLE - <u>Negligible risk of extinction</u> in the wild.
	<ul style="list-style-type: none"> LOW THREAT LEVEL - <u>Low risk of extinction</u> in the wild.
	<ul style="list-style-type: none"> MODERATELY THREATENED - <u>Moderate risk of extinction</u> in the wild.
	<ul style="list-style-type: none"> HIGHLY THREATENED - <u>High risk of extinction</u> in the wild.
	<ul style="list-style-type: none"> CRITICALLY THREATENED - <u>Extremely high risk</u> of extinction in the wild.



Now I would like you to focus on the two major Lynx groups in Poland **the LOWLAND population in the north-eastern part of Poland and the CARPATHIAN population in the southern part of Poland**

INTERVIEWER: Show map 2: Lynx distribution in Poland

The CARPATHIAN lynx population is the largest lynx population in Poland. It consists on about 100 individuals. It occurs in the south part of Poland from Bieszczady to Beskid Zywiecki and the Przemyśl Foothills. This group is part of a larger population in the Czech Republic, Slovakia, Ukraine and Romania. Taking into account the current size of the group, the area of occurrence and the possibility of migration this population can be considered as a population that is MODERATELY THREATENED. If no additional conservation measures take place in 20 years the chances of survival of this group will fall. In this case, it is likely that, this population would then be considered as **HIGHLY THREATENED**.

The LOWLAND lynx population is the second largest population of lynx in Poland, numbering about 60 individuals. It occurs in the north-eastern part of Poland in Bialowieza, Knyszynska Augustowska and the Biebrza Basin. Due to the lack of connections between large wooded forest complexes, this group is relatively isolated and is not associated with other lynx in eastern Europe. Consequently, in the Lowland lynx population are closely related with decreased genetic diversity. Taking into account the current size of the group, the area of occurrence and the possibility of migration this population can be considered as a population that is HIGHLY THREATENED. If no additional conservation measure take place in 20 years the chances of survival of this group will fall. In this case, it is likely that, this population would then be considered **CRITICALLY THREATENED**.

8. Do you consider the lynx survival in Poland as:
- a) Definitely important
 - b) Rather important
 - c) indifferent issue
 - d) Rather unimportant

d) Definitely unimportant

The lynx population status in Poland can be improved by taking adequate conservation measures. Such measures are:

*1) **creation of migration corridors between forest complexes**, i.e., buying by the government of pieces of land between forest complexes and their subsequent afforestation; building a special forested pass over roads and railway tracks.*

*2) **reducing the number of hunted game**: in this case the government will pay compensation to forest managers because of to lower fee revenues from the hunting associations.*

*3) **changes in forest management**: cease afforestation on open spaces, leaving larger amounts of dead wood in forests to create better conditions for lynx to hunt and rest. This change in management will be more costly since other forest operations will be made more difficult.*

*4) **improvement of forest monitoring in order to combat poaching.***

*5) in the case of the Baltic population, an **import of additional animals from Eastern Europe to increase genetic diversity and eliminate genetic diseases** caused by too small a number of individuals.*